

Curriculum Vitae
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With Joint Appointments in
Department of Physiology and Neurobiology and
Department of Nutritional Sciences

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Educational Background

- B.Ed.** University of Toledo 1971 cum laude Major: Biology, comprehensive science
M.Ed. University of Toledo 1976 4.00 GPA Major: Curriculum (Science)
Ph.D. Ball State University, Human Performance Laboratory 1983. Received Doctoral Fellowship in Human Bioenergetics. Dissertation topic: Effects of Dietary Sodium Intake on Body and Muscle Potassium Content in Unacclimatized Men During Successive Days of Exercise in the Heat.

Research Experience

- Doctoral Fellow, Human Performance Laboratory, Ball State University, Muncie IN. 1980 - 1983.
- Research Physiologist, human research, U.S. Army Research Institute of Environmental Medicine, Heat Research Division, Natick MA. 1983 - 1990.
- Member, Human Use Review Committee, USARIEM. 1987 - 1990
- Professor, University of Connecticut, Storrs CT. Principal investigator, Human Performance Laboratory, 1990 - present.
- Appointed member, Research Advisory Committee, Neag School of Education, 2001 - 2004
- Appointed member, Institutional Review Board for Human Subjects Research, University of Connecticut, 2004 - 2006

Administrative Experience

- *University of Connecticut, Storrs, CT:* Acting Department Head, Department of Kinesiology, undergraduate and graduate programs, Fall semester, 2007
- *National ACSM Board of Trustees*, elected member, term spans 2006 to 2008 (see Organizational Service below)
- *New England Regional Chapter of the American College of Sports Medicine:* President (500+ members), 1991 - 1992; elected member NEACSM Board of Trustees, 2004 - 2006 (see Organizational Service below)
- *University of Connecticut, Storrs, CT:* wrote, secured, administered and published the grants that appear on the final pages of this CV.
- *University of Connecticut, Storrs, CT:* Director, Sport Laboratory for People with Disabilities, and Co-Director of Human Performance Laboratory; duties included securing grants, research planning, budget management, conflict resolution, updating Athletic Training Curriculum, 1990 - 1996
- *University of Connecticut, Storrs, CT:* Faculty Advisor for the Sports Medicine/Athletic Training Concentration, Neag School of Education, 1990 - 1999
- *U.S. Army Research Institute of Environmental Medicine, Natick, MA:* directed numerous laboratory and field studies; responsibilities included budgeting, civilian & military personnel management, research planning, logistics, and conflict resolution, 1983 - 1990.
- *U.S. Army Research Institute of Environmental Medicine, Natick, MA:* active duty military service, Medical Service Corps Officer, 1983 - 1988.
- *Gorham-Fayette Local Schools, Fayette OH:* High School Principal, responsible for 20 teachers and 300 students in grades 7 - 12; oversaw curriculum, budgets, hiring staff and faculty, 1979 - 1980.
- *Gorham-Fayette Local Schools, Fayette, OH:* High School Athletic Director. Responsible for all boys and girls athletic programs, grades 7 - 12; managed budgets, transportation, scheduled contests, secured officials, 1978 - 1980.

- *Gorham-Fayette Local Schools, Fayette, OH*: Manager of numerous track & field and cross country invitational meets, 1975 - 1980.
- *Village Council, Fayette, OH*: elected to three year term; member of recreation, police, and water treatment committees; included personnel, budgetary, planning responsibilities, 1977 - 1980.

Date of Birth June 24, 1949

Teaching Experience

- *University of Connecticut, Storrs, CT*: Associate Professor, taught Thermal Physiology, Physiological Systems in Human Performance, Mechanisms & Adaptations in Sport & Exercise, Athletic Injury Assessment, Scientific Instrumentation, Exercise Metabolism, Scientific Presentations, Stressful Environments, Laboratory Analytical Techniques, Variable Topics (PNB 295), Independent Study (PNB 299, EKin 299/300, NUSC 299/300). Promoted to Associate Professor with tenure in September, 1993. Promoted to Professor in September, 2001.
- *University of Connecticut, Storrs, CT*: Joint Appointment in the Department of Physiology & Neurobiology, 1991 - present; lectured in Fundamentals of Physiology PNB 302, Spring 1999. Joint Appointment in Department of Nutritional Sciences, 1996 - present.
- *University of Connecticut, Storrs, CT*: Adjunct Professor, taught two graduate seminar courses regarding Exercise in stressful environments, Jan 1989 - May 1990.
- *Massachusetts Bay Community College, Wellesley, MA*: Instructor, taught Biology 101, Summer 1990.
- *Ball State University, Muncie, IN*: Taught undergraduate Exercise Physiology (1 term), Human Anatomy (4 terms), Human Physiology (1 term), and Graduate Lab Procedures in Human Bioenergetics (1 term), 1980-83.
- *Gorham-Fayette Local Schools, Fayette, OH*: Taught Chemistry, Physical Sci., Biology, Nutrition, 1971-80. Coached High School Cross Country, Track & Field, and Basketball for 16 seasons, 1972-1980.
- *Toledo Public Schools, Toledo, OH*: Substitute Teacher in various settings including High School Science, 1970 - 1971.

Professional Affiliations

- Member - New York Academy of Sciences, 1999-2000.
- Member - Society for Human Performance in Extreme Environments, Dayton OH, 1999-2001
- Member - National Spinal Cord Injury Assoc., CT Chapter, 1991-1995.
- Member - Federation of American Societies for Experimental Biology & American Physiological Society, 1986-present.
- Member - Aerospace Medical Association, 1986-present.
- Member - National Strength & Conditioning Association, 1986-present.
- Member - American College of Sports Medicine, 1981-present.
- Fellow - American College of Sports Medicine, 1986-present.
- Member - American Association of University Professors, 1990-present.
- Member - National Education Association, 1971-1980

Field Studies Conducted

- Effects of dehydration on physiological responses and performance of 10 k trail running. Harrison Lake State Park, Mansfield, CT. July, 2007; with Douglas Casa, Ph.D. and Rebecca Stearns, M.S.
- Hydration state of adolescent high school football players during pre-season practices. Northwest High School, Hartford CT. August, 2006; with Douglas Casa, Ph.D. and Susan Yeargin, Ph.D.
- Effects of diuretic-induced dehydration (furosemide) on power and competitive sprint performance, Storrs CT, Fall, 2003
- Heat acclimatization of university football players during the initial eight days of summer workouts. University of Connecticut, Storrs CT. One of two U.S. test sites. Sponsor: National Collegiate Athletic Association. August 2003.
- Comparison of two cooling techniques for hyperthermic runners: the finish line medical tent. Falmouth Road Race, 1992 - 1994.
- Fluid-electrolyte perturbations in collegiate tennis players during repeated days of simulated match play in a hot-humid environment. Miami University and Florida International University, FL, October 1992.
- Effects of hydration status on the performance of collegiate swimmers. The University of Connecticut, Winter 1991.
- Comparison of WBGT heat stress index to casualty rates. Medical Aid Tent, Boston Marathon, Boston, MA, April 1988 - 1992.

- Blood chemistry, total body water (D₂O) and cardiovascular observations of heat exhaustion and heat cramp patients. 44th Evacuation Hospital, Fort Hood TX, June 1988.
- Evaluation of the Botsball heat stress monitor in rain forest and jungle environments. Innisvail and Alice Springs, Australia, February 1987.
- Investigation of eleven heat exhaustion cases in Army Paratroopers. Ft. Davis, Panama. September 1985.
- Evaluation of flavoring packets to increase water consumption. Ft. Benning, Georgia. July 1985.

Awards/Honors

- Received a citation from Connecticut Governor Jodi Rell for being elected to the ACSM Board of Trustees, June 2006.
- Elected to the National Board of Trustees, American College of Sports Medicine, April 2006.
- Department of Kinesiology, University of Connecticut, was ranked the # 1 Kinesiology Doctoral Program in the United States by the American Academy of Kinesiology and Physical Education, October 2005.
- Received Outstanding Faculty Research Award, Neag School of Education, University of Connecticut, May 2005.
- Member of the *ad hoc* writing group for the N.A.T.A. Position Statement titled, *Fluid Replacement for Athletes*. This document received a 2001 Gold Circle Award from the American Society of Association Executives, January 2002.
- Received Honor Award for Exemplary Service to the New England Chapter of ACSM, Boxborough MA, November 1996.
- Received Provost's Monetary Award for Academic and Research Excellence, University of Connecticut, 1994, 1996, 1997, 1999, 2001, 2005.
- Received National Strength and Conditioning Association's Presidential Award for contributions to the NSCA Journal in Environmental Physiology, May 1993. Second award, see May 1989.
- Nominated for the Outstanding Sport Scientist Award, National Strength & Conditioning Association, St. Louis MO, June 1991.
- Received Department of the Army Achievement Medal for Civilian Service, Heat Research Division, USARIEM, Natick, MA, June 1990.
- Received U.S. Army Meritorious Service Medal for human research involving heat physiology, Natick MA, December 1990.
- Received U.S. Department of the Army Exceptional Performance Award for human research program on recovering heatstroke patients, Natick, MA, June 1989.
- Received National Strength and Conditioning Association's Presidential Award for contributions to the NSCA Journal in Environmental Physiology, May 1989.
- Received U.S. Army Commendation Medal for meritorious service in Medical Research & Development, Natick, MA, Nov 1987.
- Received Aerospace Medical Association's annual Environmental Science Award, sponsored by the McDonell-Douglas Corp. Nashville, TN, April 1986.
- Doctoral Fellowship in Human Bioenergetics, Ball State University, Human Performance Laboratory, 1980 - 1983.
- Named Acker Outstanding Science Teacher of Northwest Ohio, by Ohio Academy of Sciences, Toledo OH, November 1978.
- Named Mid-American Conference Scholar/Athlete, Univ. of Toledo, Cross Country and Track & Field, 1968-69

Awards: Doctoral Student Advisees

- NiCole Keith received the Outstanding Minority Graduate Student award, New England ACSM, 1997.
- Stavros A. Kavouras received the annual Outstanding Young Investigator Award at the annual meeting of the American Physiological Society, Environmental & Exercise Physiology Section, San Francisco CA, 1998 [major advisor].
- Brian E. Miller received the annual National Student Research Award at the annual meeting of the American College of Sports Medicine [ACSM], Seattle WA, 1999 [doctoral committee member].
- Douglas R. Bolster received the ACSM National Student Research Award at the annual meeting of the American College of Sports Medicine, Baltimore MD, 2001 [co-major advisor].
- Douglas J. Casa received the Speer Award for Outstanding Research at the annual meeting of the National Athletic Trainers Association, Dallas TX, 2001 (doctoral committee member).
- Melissa L. Roti received the Outstanding Doctoral Student Research Award for her presentation at the annual conference of New England ACSM, Providence RI, November 2003 (doctoral committee member).
- Susan Yeargin received the Outstanding Doctoral Student Research Award for her presentation at the annual conference of New England ACSM, Providence RI, November 2006 (doctoral committee member).

Moderator/Chair of Scientific Sessions

- Conference Co-Chair, International Life Sciences Institute Hydration Conference, Washington, D.C., Nov. 29 - 30, 2006
- Chair - ACSM Symposium, "Moderate Caffeine Intake: Physiological, Psychological and Exercise Performance Effects", Denver CO, June 2006
- Chair - ACSM Free Communication Session, "Sodium balance in Exercise", National Conference, Nashville, TN, June 2005.
- Co-Chair - ACSM Symposium, "International Perspectives on Exertional Heatstroke: A 15-Year Follow-up", National Conference, Indianapolis, IN, June 2004.
- Chair - NEACSM Symposium, "Sixty-three percent of body weight: science, myths and interesting facts about human hydration." Annual Conference, Providence RI, Nov. 2003.
- Moderator - NEACSM Symposium, "Publishing: Navigating the System", Annual Conference, Providence RI, Nov. 2000
- Co-Moderator - ACSM Colloquium titled, "Benefits and limitations of tympanic and aural temperatures in sports medicine and research", National Conference, Indianapolis, IN, June 1994
- Moderator - New England ACSM Seminar, "Exercise-induced fluid-electrolyte and performance perturbations in stressful environments", Marlborough, MA, Nov. 1990.
- Co-Chair - ACSM Symposium, "Exertional Heatstroke: An International Perspective", National Conference, Baltimore, MD, June 1989.
- Moderator - NSCA Free Communications Session, "Strength analysis: influence of neural and body composition factors." Annual meeting, Orlando, FL, June 1988.
- Chair - New England ACSM Seminar, "The Environment and Human Performance", Worcester, MA, Nov. 1987.

Organizational Service

- Appointed to Provost's Task Force on Teaching, Learning and Assessment, Univ. Connecticut, 2006 - 2007.
- Elected to National ACSM Board of Trustees, June, 2006 - June, 2008 (see Administrative Experience above)
- Chairperson, Student and Past-Presidents Luncheon, annual conference of NE ACSM, Providence RI, Nov 2005
- Appointed to the National ACSM Diversity Task Force. Purpose: to increase representation of under-represented minority members in ACSM. January 2004 - present.
- Appointed as Chairperson of the annual Faculty PTR Forum, Univ. of Connecticut, 2003 to present (see Administrative Experience above)
- Appointed to Provost's Task Force: Gender and Racial Bias in Teaching Evaluations, Univ. Connecticut, 2004 - 2006.
- Invited Member of ACSM Consensus Conference re. Hydration and Physical Activity. Boston, MA, December 2003.
- Elected, Board of Trustees Representative, New England Chapter of ACSM, 2-year term, 2004 - present
- Appointed to Faculty Standards Committee of University Senate. University of Connecticut, 2002-present; appointed Chairperson, April 2003
- Appointed - National Academy of Sciences, Institute of Medicine, Subcommittee on Specifications for a High-Energy Emergency Relief Food Product, to develop an emergency food ration for humanitarian efforts in countries such as Bosnia and Rwanda. Washington, D.C., 2001 - 2002.
- Elected - 3-year term on the University of Connecticut Faculty Senate, Representing the Neag School of Education, July 2001 - 2004
- Appointed - National Academy of Sciences, Institute of Medicine, Subcommittee on Military Weight Management, January, 2000 - 2001
- Appointed - National ACSM Constitution, By-Laws & Operating Codes Committee, 1999-2002; appointed Chairperson, June 2001-2003; reappointed in 2004 as Chair for a three-year term
- Appointed - Veteran's Administration, *ad hoc* Grant Peer Review Committee, Washington, D.C., June 1999
- Appointed - National Athletic Trainers Association, *ad hoc* Committee to write Position Statement: Fluid Replacement for Athletes, 1999
- Appointed - National Academy of Sciences, Institute of Medicine, Committee on Military Nutrition Research, Washington D.C., 1998-2001
- Appointed - Advisor to the Board of Trustees, Sport Sciences Academy, Hartford Public Schools, 1998-1999
- Appointed - Media Referral Network, National ACSM, 1998 - present
- Appointed - Ethics and Professional Conduct Committee, National ACSM, 1996-1999

- Appointed - University President's Committee on The Americans with Disabilities Act, Univ. of Connecticut, 1997 -- present
- Service - University of Connecticut, Commencement Committee, Floor Marshall, 1997-2001
- Member - New England Chapter of ACSM, Board of Trustees, 1992 - present
- Appointed - Abstract Peer Review Committee, New England Chapter of ACSM annual meeting, 1986 - 1989, 1995
- Appointed - Abstract Peer Review Committee, Environmental Physiology, National ACSM annual meeting, 1986 - 1989, 1995
- Appointed - Advisor to Board of Directors, The Tolland Foundation, CT, 1994 - 1997
- Appointed - Chair, National ACSM Writing Group for Position Stand on "Heat and Cold Illnesses During Distance Running", 1994 - 1996
- Appointed - *Max! Newsletter* Editor, New England Chapter of ACSM, 1993 - 1998
- Appointed - Research Awards Committee, National ACSM, 1993 - 1996
- Appointed - National Strength & Conditioning Association Technical Advisory Committee, 1992 - 1993
- Appointed - Minority Membership Committee, National ACSM, 1992 - 1994
- Appointed - Pronouncements Committee, National ACSM, 1992 - 1995
- Appointed - National Strength & Conditioning Association Research Committee, 1991 - 1993
- Organized - Gunnar Borg Lecture Tour of New England, Nov. 1991
- Elected as President - New England Chapter of ACSM, Nov. 1991 - Nov. 1992
- Appointed - National Strength & Conditioning Association, Abstract Review Committee, St. Louis MO, 1991 - 1993
- Appointed - Chairman, New England ACSM, Honor Awards Committee, 1989 - 1990
- Appointed - ACSM National *ad hoc* Writing Group to write Position Stand on "Exercise and Fluid Replacement", 1988 - 1989; 1993 - 1995
- Appointed - ACSM National Project Review Committee, April 1988 - 1991
- Appointed - Chairman, New England ACSM, Free Communications Sessions, Worcester, MA, 1986-1988
- Elected - 2-year term as Executive Committee Member, New England Chapter of American College of Sports Medicine [ACSM], Boxboro, MA, November 1986

Journal Editorial Board and Peer Review Activities

- Appointed, Book Review Editor for *Medicine & Science in Sports & Exercise*, 2005-present
- Editorial Board Member for *Journal of Athletic Training*, 2004-2008
- Editorial Board Member for *Medicine & Science in Sports & Exercise*, 2000-present
- Editorial Review Board Member for *International Journal of Sport Nutrition & Exercise Metabolism*, 1990 - 1993; 1998-present (second appointment)
- Developmental Task member Force & Editorial Board Member for *Journal of Strength and Conditioning Research* (formerly *Journal Applied Sport Science Research*), 1987-present
- Associate Editor for *National Strength & Conditioning Association Journal*, 1985-1988
- Editorial Advisory Board Member for *Medicine, Exercise, Nutrition, and Health*, 1991-1995
- Editorial Board Member for *J. Human Muscle Performance*, 1990-1991
- Peer Reviewer for the following journals: *Journal of Athletic Training*, 1999-present; *European Journal of Applied Physiology & Occupational Physiology*, 1997-2003; *British Journal of Sports Medicine*, 1996; *Sports Medicine (New Zealand)*, 1993-present; *International Journal of Sport Nutrition & Exercise Metabolism*, 1993-present; *Journal of Applied Physiology*, 1991-present; *Research Quarterly for Exercise & Sport*, 1990-1993; *Medicine & Science in Sports & Exercise*, 1986-present; *The Physician & Sports Medicine*, 1986-1991; *Aviation, Space & Environmental Medicine*, 1985-present; *International Journal of Sports Medicine*, 1982-1999; *Pediatric Exercise Science*, 2000-2002; *Journal of Sports Sciences*, 2005-present.

Relevant Professional Experiences

- Paid Consultant, Exertional heatstroke death of a professional football player, 2007 - present
- Appointed to the Scientific Advisory Board, Cantimer Inc., Menlo Park, CA, 2006 - present
- Paid Consultant to The Beverage Institute for Health & Wellness, Coca Cola Inc., Atlanta GA, 2006
- Appointed to Scientific Advisory Board, Shaklee Inc., Pleasanton CA, 2006 - present
- Paid Consultant to International Olympic Committee, developed education materials for credentialing program, 2006

- Completed CITI online training for Institutional Review Board Members, Sept. 2005, Univ. of Miami (CR# 161377)
- Paid Consultant, Nestle' Waters Division, Lausanne Switzerland, 2005 - 2006
- Appointed to Dean's Doctoral Program Review Committee, Neag School of Education, University of Connecticut, 2005
- Paid Consultant, Beverage Panel to design a fluid consumption pyramid for public use, Unilever Inc., 2005
- Appointed to Provost's Task Force, Bias in Teaching Evaluations, 2004 - 2006
- Paid Consultant, Exertional heatstroke death of a professional baseball player, 2004 - 2005
- Paid Consultant, Exertional heatstroke death of teenage roller hockey player, Florida, 2004 - present.
- Member, Institutional Review Board for Human Studies, University of Connecticut, 2004 - 2007
- Paid Consultant, Design of core body temperature telemetry device, HQ Inc., 2004
- Paid Consultant, Liability suit involving a university tennis player's intake of sodium, Florida, 2003.
- Paid Consultant, Design of educational materials for U.S. military personnel regarding environmental illnesses, National Strength & Conditioning Association, 2003
- Paid Consultant, Heatstroke death of high school football player in Indiana, 2003
- Paid Consultant, Caffeine effects on body fluid-electrolyte balance. International Life Science Institute, Washington D.C., 2002 and 2003
- Appointed to Promotion Tenure and Reappointment Committee, Neag School of Education, 2001 - 2003
- Appointed to Research Awards Committee, Neag School of Education, 2001 -2003.
- Appointed to Research Advisory Council, Neag School of Education, 2001-2003.
- Paid Consultant, Review of the scientific literature re. caffeine, diuresis, body fluid balance, and exercise performance, National Coffee Association, New York, NY, 2001
- Appointed, Dept. of Kinesiology, Graduate Admissions Committee, 2000
- Paid Consultant, Design of an interactive web site that predicts water needs in variety of situations. Water.com, Inc., Atlanta, GA., 2000
- Paid Consultant, Design of an experiment to test an osmolyte-containing beverage during cycling in a hot environment, Danisco Cultor, Ardsley, NY., 2000
- Paid Consultant, Physiological factors associated with sport drinks, Consumer Eyes Inc., New York City, NY, 2000
- Paid Consultant, Hyponatremia in a marathon runner leading to loss of occupation, Law Firm of Thorsnes, Bartolla & McGuire, San Diego, CA, 2000
- Paid Consultant, Heatstroke death of a waste collection laborer, City of San Antonio, TX, 1999
- Appointed, Department of Kinesiology, Exercise Program Coordinator, 1999-2001
- Paid Consultant, Effects of Hot Environments on golf performance, U.S.Golf Association and Center for Clinical & Lifestyle Research, MA, 1998
- Appointed - Organizational Climate Committee, School of Education, University of Connecticut, 1998
- Licensed Investigator to oversee use of radioactive materials in the Human Performance Laboratory, University of Connecticut, 1997
- Unpaid consultant, American College of Sports Medicine's Media Referral network, Topics: fluid-electrolyte balance, exercise in heat, Indianapolis, IN, 1997-present.
- Reviewed Costill/Wilmore and Wilmore/Kenney textbook for Human Kinetics Publishers, 1997 and 2005
- Appointed - Female Athlete Performance Committee, Athletic Department, University of Connecticut, 1997-present
- Paid Consultant, Heatstroke death of junior high football player, Fayetteville AK, 1996
- Consultant, Defense Women's Health Research Program, Peer Reviewer for research proposals, Baltimore MD, 1996
- Paid Consultant, Heatstroke death of mountain biker, Philadelphia PA, 1995-1997
- Appointed - Ph.D. Dissertation Proposal Review Committee, University of Connecticut, School of Education, 1995 - 2001
- Paid Consultant - Procter & Gamble Co., Cincinnati, OH, Food & Beverage Technology Division, Fall 1992; & Health Care Division, Spring 1993
- Appointed - Curriculum & Courses Committee, University of Connecticut, The School of Education, 1991 - 1995
- Uncompensated Consultant - Gatorade "Heat Wave" media informational source, 1991-1993 (unpaid)
- Speaker - Accredited Video Educational Production titled, "Heat Illnesses", produced by CME Video, Dallas, TX, May 1992
- Appointed - Environmental Health & Safety Committee, University of Connecticut, 1991 - 1992
- Expert witness - Inquest re. the death of police cadet, District Court of Massachusetts, March 1989 (unpaid)
- Co-host of Public Television production of "Sweating it Out", WGBH-TV, Boston, MA. Produced by Bank Street College, February 1989

- Contract Office Technical Representative, USAMRDC, Natick, MA; served as U.S. Government Contract Rep., Tuskegee Institute, 1985 - 1990.

Published Books

1. Armstrong L.E. *Performing in Extreme Environments*. Human Kinetics Publishers, 2000, 334 pages.
2. Armstrong, L.E., editor and author/coauthor of six chapters. *Exertional Heat Illnesses*. Human Kinetics Publishers, April 2003, 275 pages. Individual chapters are listed in the section below titled, "Book Chapters".

Special Journal Supplement

1. Armstrong, L.E. and Grandjean, A.C. Guest Editors. Special supplement to the *Journal of the American College of Nutrition* 26(5), 2007. This supplement presented conference proceedings of the Hydration & Health Promotions Conference, Washington D.C., November 29-30, 2006.

Publications in Refereed Journals

1. Sherman, W.M., Costill, D.L., Fink, W.J., Armstrong, L.E., Hagerman, F.C., Murray, T.M. The effect of a 42.2 km foot race and subsequent rest or exercise on muscle glycogen and enzymes. *J. Appl. Physiol.* 55(4):1219-1224, 1983.
2. Armstrong, L.E., Winant, D.M., Swasey, P.R., Seidle, M., Carter, L.R., Gehlsen, G. Using isokinetic dynamometry to test ambulatory patients with Multiple Sclerosis. *Physical Therapy* 63(8):1274-1279, 1983.
3. Sharp, R.L., Armstrong, L.E., King, D.S., Costill, D.L. Buffer capacity of blood in endurance trained and untrained subjects. *Biochemistry of Exercise-V*, p.595, 1983.
4. Sherman, W.M., Costill, D.L., Fink, W.J., Armstrong, L.E., Hagerman, F.C., Murray, T.M. The marathon: Acute recovery from biochemical alterations. *Biochemistry of Exercise-V*, pp.312, 1983.
5. Katz, A., Sharp, R.L., Armstrong, L.E., King, D.S. Oxygen tension in antecubital blood of trained and untrained males following maximal leg exercise. *Can. J. Appl. Sports Sci.* 9(1):11-15, 1984.
6. Sherman, W.M., Armstrong, L.E., Murray, T.M., Hagerman, F.C., Costill, D.L., Staron, R.C., Ivy, J.L. The effect of a 42.2 km foot race and subsequent rest or exercise on the recovery of muscular strength and work capacity. *J. Appl. Physiol.* 57(6):1668-1673, 1984.
7. Armstrong, L.E., Costill, D.L. Variability of respiration and metabolism: responses to submaximal cycling and running. *Res Qtrly for Ex & Sport* 56(2):93-96, 1985.
8. Armstrong, L.E., Costill, D.L., Fink, W.J. Influence of Diuretic-Induced Dehydration on Competitive Running Performance. *Medicine and Science in Sport & Exercise*, 17(4): 456-461, 1985.
9. Armstrong, L.E., Costill, D.L., Fink, W.J., Bassett, D., Hargreaves, J., Nishibata, I., King, D.S. Effects of Dietary Sodium on Body and Muscle Potassium Content During Heat Acclimation. *European Journal of Applied Physiology*, 54:391- 397, 1985.
10. Armstrong, L.E., Hubbard, R.W., Szlyk, P.C., Matthew, W.T., Sils, I. V. Voluntary Dehydration and Electrolyte Losses During Prolonged Exercise in the Heat. *Aviation, Space and Environmental Medicine*, 56:765-770, 1985.
11. Armstrong, L.E., Costill D.L., Fink, W.J. Changes in body water and electrolytes during heat acclimation: effects of dietary sodium. *Aviation, Space and Environmental Medicine*, 58:143-148, 1987.
12. Armstrong, L.E., Hubbard, R.W., DeLuca, J.P., Christensen, E.L. Heat acclimatization during summer running in Northeastern United States. *Medicine and Science in Sport & Exercise*, 19(2):131-136, 1987.
13. Armstrong, L.E., Hubbard, R.W., DeLuca, J.P., Christensen, E.L. Kraemer, W.J. Evaluation of a temperate environment test to predict heat tolerance. *European Journal of Applied Physiology* 56:384-389, 1987.
14. Kraemer, W.J., Armstrong, L.E., Marchitelli, L.J., Hubbard, R.W., Leva, N. Plasma opioid peptide responses during heat acclimation in humans. *Peptides*, 8:715-719, 1987.
15. Szlyk, P.C., Hubbard, R.W., Matthew, W.T., Armstrong, L.E. Kerstein, M.D. Mechanisms of voluntary dehydration among troops in the field. *Military Medicine* 152:405-407, 1987.
16. Matthew, W.T., Hubbard, R.W., Szlyk, P.C., Armstrong, L.E. Kerstein, M.D. Monitoring of heat stress. *Military Medicine* 152:399-404, 1987.
17. Armstrong, L.E., Hubbard, R.W., Szlyk, P.C., Sils, I.V. Kraemer, W.J. Heat intolerance, heat exhaustion monitored: a case report. *Aviat. Space Environ. Med.*, 59:262-266, 1988.
18. Armstrong, L.E., Hubbard, R.W., Kraemer, W.J., DeLuca, J.P., Christensen, E.L. Signs and symptoms of heat exhaustion during strenuous exercise. *Annals of Sports Medicine*, 3:182-189, 1988.

19. Kraemer, W.J., Armstrong, L.E., Hubbard, R.W., Marchitelli, L.J., Leva, N., Rock, P.B. Responses of plasma human atrial natriuretic factor to high intensity submaximal exercise in the heat. *European J. Applied Physiol.* 57:399-403, 1988.
20. Hubbard, R.W., Armstrong, L.E., Young, A.J. Rapid hypothermia subsequent to oral nicotinic acid ingestion and immersion in warm (30°C) water. Correspondence. *Am J Emergency Medicine* 6:316-317, 1988.
21. Armstrong, L.E., Hubbard, R.W., Epstein, Y., Weien, R. Nonconventional remission of miliaria rubra during heat acclimation: case study. *Military Medicine* 153:402-404, 1988.
22. Armstrong, L.E., Francesconi, R.P., Kraemer, W.J., Leva, N., De Luca, J.P., Hubbard, R.W. Plasma cortisol, renin, and aldosterone during an intense heat acclimation program. *International J Sports Medicine* 10(1):38-42, 1989.
23. DuBose, D.A., Armstrong, L.E., Kraemer, W.J., Lukason, M. Modulation of human plasma fibronectin levels following exercise. *Aviation, Space and Environ Med* 60:241-245, 1989.
24. Szlyk, P.C., Sils, I.V., Francesconi, R.P., Hubbard, R.W., Armstrong, L.E. Effects of water temperature and flavoring on voluntary dehydration in men. *Physiol Behav* 45:639-647, 1989.
25. Armstrong, L.E., De Luca, J.P., Hubbard, R.W. Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. *Medicine & Science in Sports & Exercise* 22:36-48, 1990.
26. Armstrong, L.E., Hubbard, R.W. Application of a model of exertional heatstroke pathophysiology to cocaine intoxication. *American J Emergency Medicine* 8:178, 1990.
27. Armstrong, L.E., Hubbard, R.W., Christensen, E.L., De Luca J.P. Evaluation of a temperate environment test of heat tolerance in prior heatstroke patients and controls. *Eur J Appl Physiol* 60:202-208, 1990.
28. Armstrong, L.E., De Luca, J.P., Christensen, E.L., Hubbard, R.W. Mass-to-surface area index in a large cohort. *Am J Physical Anthropology* 83:321-329, 1990.
29. Armstrong L.E., Szlyk P.C., Sils I.V., De Luca J.P., Hubbard R.W. Prediction of the exercise-heat tolerance of males wearing protective clothing. *Aviat Space & Environ Med* 62:673-677, 1991.
30. Hoffman J.R., Maresh C.M., Armstrong L.E., Kraemer W.J. Effects of off-season and in-season resistance training programs on a collegiate male basketball team. *J Human Muscle Performance*, 1(2):48-55, 1991.
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Position Statements of National Sports Medicine Organizations

1. Convertino V.A., Armstrong L.E., Coyle E.F., Mack G.W., Sawka M.N., Senay L.C., Sherman W.M. Exercise and Fluid Replacement. American College of Sports Medicine Position Stand. *Med. Sci. Sports Exerc.* 28(10): i-vii, 1996.
2. Armstrong L.E., Epstein Y., Greenleaf J.E., Haymes E.M., Hubbard R.W., Roberts W.O., Thompson P.D. Heat and cold illnesses during distance running. American College of Sports Medicine Position Stand. *Med. Sci. Sports Exerc.* 28(12): i-x, 1996.
3. Casa D.J., Armstrong L.E., Hillman S.K., Montain S.J., Reiff R.V., Rich B.S., Roberts W.O., Stone J.A. National Athletic Trainers' Association Position Statement: Fluid replacement for athletes. *J. Athletic Training* 35(2):212-224, 2000.
4. Armstrong LE, Casa DJ, Millard-Stafford M, Moran D, Pyne S, Roberts WO. American College of Sports Medicine Position Stand: Exertional Heat Illnesses During Training & Competition. *Med. Sci. Sports Exerc.* 39(3): 556-572, 2007.

Publications of the National Academy of Sciences, Institute of Medicine

The following publications resulted from service as a member of writing committees, Institute of Medicine, Food and Nutrition Board, Committee on Military Nutrition Research:

1. *The Role of Protein and Amino Acids in Sustaining and Enhancing Performance*. Washington D.C.: National Academy Press, 1999, 429 pages.
2. *Military Strategies for Sustainment of Nutrition and Immune Function in the Field*. Washington D.C.: National Academy Press, 1999, 708 pages.
3. *Caffeine for Sustainment of Mental Task Performance: Formulations for Military Operations*. Washington D.C.: National Academy Press, 2001, 157 pages.

4. *High-Energy, Nutrient-Dense Emergency Relief Food Product*. Washington D.C.: National Academy Press, 2002, 143 pages.

USTA, USOC, IOC, & FIFA: Lectures & Publications

1. Armstrong, L.E. Effects of cold and hot environments on athletic performance. Lecture to Olympic Coaches Conference, U.S. Olympic Training Center, Colorado Springs, CO, October 1988 and December 1988.
2. Armstrong, L.E., Casa D.J. Understanding and identifying dehydration in athletes. *Olympic Coach*, 10(1):8-10, Winter 2000. Distributed to all U.S. Olympic Team Coaches.
3. Armstrong, L.E. Keeping Your Cool in Barcelona. Booklet distributed to approx. 2,000 athletes participating in 1992 Summer Olympic Games. Published by U.S. Olympic Committee, Colorado Springs, April 1992.
4. Armstrong, L.E. The effects of heat, humidity, and dehydration on athletic performance, strength, and endurance. Booklet distributed to all coaches participating in the 1992 Summer Olympic Games. Published by U.S. Olympic Committee, Colorado Springs, April 1992.
5. University of Connecticut, Storrs, CT: Director, three summer conferences for elite wheelchair athletes. Responsibilities included oversight of lodging, meals, transportation, daily schedules, research data collection, social activities; June 1991, June 1992, July 1993. 1993 conference was funded by US Olympic Committee and National Wheelchair Athletic Assoc.
6. Invited participant, *ad hoc* writing group, International Olympic Committee Consensus Conference on Nutrition in Sport, Lausanne, Switzerland, June 2003.
7. Armstrong, L.E. Two lectures: (a) Air pollution: effects on performance and potential acclimatization strategies. (b) Hydration strategies for optimal performance. Invited speaker at the U.S. Olympic Committee Conference on Heat, Humidity and Air Pollution: Preparation for Athens 2004. Colorado Springs, CO, Sept. 2003.
8. USOC distributed urine color chart to athletes participating in 2004 Summer Olympic Games.
9. Onsite consultant to athletes and coaches, Summer Olympics, Athens, Greece, Aug. 2004
10. Armstrong L.E. Research specific to Triathlon Training and Performance. U.S. Olympic Training Center, Colorado Springs, CO. Lecture at USA Triathlon Level III Coaches Course. Nov. 2004.
11. Armstrong, L.E. Nutritional Interventions for Soccer: Counteracting Heat, Cold, High Altitude and Jet Lag. Zurich, Switzerland. Lecture at Fédération Internationale de Football Association (FIFA) Consensus Conference on Nutrition and Football. August 2005.
12. Armstrong, L.E. Hydration and Nutritional Needs of the Olympic Distance (ITU) and Long-Distance Elite Triathlete. USA Triathlon Conference, Colorado Springs, CO. Feb. 2006
13. Armstrong, L.E. Preparing for Heat and Humidity. USA Cycling Conference, Colorado Springs, CO. Oct. 2006.
14. Armstrong, L.E. Sport Drink Considerations. USA Cycling Conference, Colorado Springs, CO. Oct. 2006.

Medical Tent Data Collection and Advising at Mass Participation Events

1. Boston Marathon, Boston, MA, April of each year: 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995
2. Falmouth Road Race, Falmouth, MA, August of each year: 1992, 1993, 1994, 1999, 2000
3. Marine Corps Marathon, Washington, D.C., October of each year: 2005, 2006, 2007
4. Hotter 'n Hell Hundred [100-mile cycling event], Wichita Falls, TX. August 2007

Book Chapters

1. Hubbard, R.W., Armstrong, L.E., Evans, P.K., Deluca, J.P. Long-Term Salt and Water Deficits: A Military Perspective. In: *Predicting Decrements in Military Performance Due to Inadequate Nutrition*. Washington DC: National Academy Press, 1986, pp. 29-53.
2. Armstrong, L.E., Dziados, J.E. Effects of Heat Exposure on the Exercising Adult. In: *Sports Physical Therapy*, D.B. Bernhardt, ed. New York: Churchill Livingstone Publishing Co., 1986, pp. 197-214.
3. Matthew, W.T., Thomas, G.J., Armstrong, L.E., Hubbard, R.W. Conversion of Wet Globe Thermometer (WGT) Measurements to Equivalent Wet Bulb Globe Temperature (WBGT) Index. In: *Trends in Ergonomics/Human Factors IV*. Amsterdam: Elsevier Science Publishers, 1987, pp. 367-374.
4. Armstrong, L.E., Pandolf, K.B. Physical Training, Cardiorespiratory Physical Fitness and Exercise-Heat Tolerance. In: *Human Performance Physiology and Environmental Medicine at Terrestrial Extremes*, K.B. Pandolf, M.N. Sawka, R.R. Gonzalez, eds. Indianapolis: Benchmark Press, 1988, pp. 199-226.

5. Hubbard, R.W., Armstrong, L.E. The Heat Illnesses: Biochemical, Ultrastructural and Fluid-Electrolyte Considerations. In: *Human Performance Physiology and Environmental Medicine at Terrestrial Extremes*, K.B. Pandolf editor. Indianapolis: Benchmark Press, 1988, pp. 305-359.
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50. Armstrong L.E. Exertional Hyponatremia: Eight Unresolved Questions. National ACSM Conference, Indianapolis IN, June 4, 2004.
51. Armstrong L.E. Controlling body temperature in hot and cold environments: neurotransmitters, neural plasticity, and hormones. Annual Conference of New England Chapter, ACSM. Providence, RI. November 12, 2004.
52. Armstrong L.E. Hydration and Performance: Field and Event Studies. Featured Science Symposium presented at Annual ACSM Conference, Denver CO, June 2006.

53. Armstrong L.E. Does Caffeine Chronically Alter Fluid and Electrolyte Balance or Thermoregulation in Humans? Symposium presentation at Annual ACSM Conference, Denver CO, June 2006.
54. Armstrong L.E. ACSM Position Stand: Exertional Heat Illnesses During Training and Competition. Annual Conference of New England Chapter, ACSM. Providence, RI. November, 2006.
55. Armstrong L.E. Caffeine. Part of seminar titled Influence of Nutritional Supplements on Exercise-heat Tolerance and Hydration Status. Annual National ACSM Conference, New Orleans, LA. May, 2007.
56. Armstrong L.E. Review of the new ACSM Position Stand: Exertional Heat Illnesses During Training and Competition. Annual National ACSM Conference, New Orleans, LA. May, 2007.
57. Armstrong L.E. Predisposing factors for exertional heatstroke. Annual Conference of New England Chapter, ACSM. Providence, RI. November 15, 2007.

Invited Lectures & Keynote Addresses

1. Armstrong, L.E., Durkot, M. Salt and Water Depletion Dehydration. Presented to MEDDAC Staff, Cutler Army Hospital, Ft. Devens, MA, April 1984.
2. Armstrong, L.E., Hubbard, R.W. Prevention of Heat Illness and Dehydration in the Desert. Presented to 197th Inf Bde, 1st ITB, 2d ITB, MEDDAC Staff, Ft. Benning, GA, and Martin Army Hospital, June 1984.
3. Armstrong, L.E. Hypohydration and Performance: Salt and/or Water Imbalance. Current Concepts in Environmental Medicine Conference, Natick, MA, June 1984.
4. Armstrong, L.E. and Hubbard, R.W. Long-Term Salt and Water Deficits: A Military Perspective. Presented to National Research Council, Committee on Military Nutrition, Washington DC, October, 1984.
5. Armstrong, L.E. Prevention of Heat Injury in MOPP IV Chemical Protective Gear. Presented at Iowa National Guard Conference, Camp Dodge, IA, February, 1985.
6. Armstrong, L.E. Heat Injury, Heat Stress Monitors and Protective Clothing in the Nuclear Power Plant. Presented at Bi-annual meeting of New England Nuclear Power Plant Health & Safety Officials, Maine Yankee Nuclear Power Plant, Wiscasset, ME, July, 1985.
7. Armstrong, L.E. Heat Illness: Considerations for the Flight Surgeon. Aeromedical Center, Lyster Hospital, Dothan, AL, August 1985, October 1985, March 1986, September 1986, November 1986, March 1987, August 1987, November 1987, March 1988, November 1988, February 1989, August 1989, October 1989, January 1990, March 1990.
8. Armstrong, L.E. Dehydration, Exercise, and Prevention of Heat Injury in the Reserve Component. 122d Army Reserve Command, San Antonio, TX, March, 1986.
9. Armstrong, L.E. Running in the heat. American Medical Joggers Association annual meeting, Boston, MA, April, 1986.
10. Armstrong, L.E. High and Dry: Can We Avoid High Body Temperature and Dehydration on the run? Wright State University Seminar, Total Fitness Lifestyle Division, Dayton, OH, April, 1986.
11. Armstrong, L.E. Desert Living and Heat Casualties. 351st General Hospital, U.S. Army Reserve, Hanscom Air Force Base, MA, May, 1986.
12. Armstrong, L.E. Heat Stroke and the EMT. Paramedic Services Division, Marlborough Hospital, MA. June, 1986.
13. Armstrong, L.E. Recent Research Findings: Heat Research Div, USARIEM. Physicians Seminar Series, Cutler Army Hospital, MA June, 1986.
14. Armstrong, L.E. Heat Injury Research for the Clinician. Physicians Seminar, U.S. Army Hospital, West Point Military Academy, New York. July, 1986.
15. Armstrong, L.E. Preventive Medicine Aspects of Heat Illness. Epidemiology of Non-infectious Diseases course, F.E. Herbert School of Medicine, Bethesda, MD. July, 1986.
16. Armstrong, L.E. Water intake in protective clothing: investigation of two water delivery systems. Tenth annual meeting of Water Resources Management Action Group, Ft. Belvoir, VA. September, 1986.
17. Armstrong, L.E. Desert & jungle survival for the Army Aviator. Aviation Safety Workshop: 26 Avn Bde/Otis AFB, Natick, MA, March 1987.
18. Armstrong, L.E. Heat Injury: Predisposition, Recognition and Prevention. Medical Staff Seminar, Ireland Army Hospital, Ft. Knox, KY, April 1987.
19. Armstrong, L.E. Thermoregulatory evaluation of former heatstroke patients. Medical staff, Martin Hospital, Ft. Benning, GA, June, 1987.
20. Armstrong, L.E. Leadership responsibilities in prevention of heat illness and training. Fifth U.S. Army Reserves Annual Training Conference, Oklahoma City, OK, August 1987.

21. Armstrong, L.E. Heat injury prevention in arid and tropical environments. 101st Airborne Division, Fort Campbell, KY, April 1988.
22. Armstrong, L.E. Running in the Heat. Seminar, Health Fair, Central Mass Striders, Worcester, MA, April 1988.
23. Armstrong, L.E. Emergency Medical Treatment of heat illness. Emerson Hospital, Concord MA, May 1988.
24. Armstrong, L.E. Field recognition of heat injuries. 44th Evacuation Hospital, Fort Hood, TX, June 1988.
25. Armstrong, L.E. Practical ways to avoid heat illness. Cedardale Athletic Club, Haverill, MA, June 1988.
26. Armstrong, L.E. Time course and recovery in prior heatstroke patients. Preventive Medicine Officer Conference, Baltimore, MD, Sept 1988.
27. Armstrong, L.E. Effects of air pollution, altitude, cold and heat on cardiac rehabilitation patients. Physician Seminar, Newton-Wellesley Hospital, Newton, MA, November 1988.
28. Armstrong, L.E. Heat injury prevention in armored engineering units. Fifth U.S. Army Reserves, Dallas, TX, October 1988.
29. Armstrong, L.E. Army Scenarios and Carbohydrate-Electrolyte Beverage Use. Workshop on the Use of Carbohydrate-Electrolyte Solutions by Soldiers in the Field, Committee on Military Nutrition, Nat. Academy of Sciences, Washington, DC, Feb 1989.
30. Armstrong, L.E. Fluid, electrolyte and carbohydrate needs of athletes. NSCA Conference, Yale University, New Haven, CT, March 1989.
31. Armstrong, L.E. Heat illness, dehydration, and environmental monitoring. Moore Army Airfield, Ayer, MA., May 1989.
32. Armstrong, L.E. Emergency management of common heat illnesses. Physician and EMT seminar, St. Joseph's Hospital, Lowell, MA, April 1990.
33. Armstrong, L.E., De Luca, J.P., Hubbard, R.W. Exertional heatstroke in soldiers: an analysis of recovery rates, predisposing factors, and residual heat intolerance. Annual Army Science Conf., Durham, NC, June 1990.
34. Armstrong, L.E. Salt requirements while living in a hot environment. Food and Nutrition Board, National Academy of Sciences, Washington, DC, November 1990.
35. Armstrong L.E. Hot weather running: clothing, fluids, acclimatization. Race Seminar, Shenipset Striders, Rockville, CT, February 1991.
36. Armstrong L.E., Hubbard R.W., Askew E.W., Moore R.J., Francesconi R.P., Johnson R.F. The effects of consuming 8g and 4g of sodium chloride per day on physiologic, clinical, and fluid-electrolyte responses during 10 days of exercise-heat exposure. Interagency Committee, National Institutes of Health, Bethesda, MD, February 1991.
37. Armstrong L.E., Maresh C.M. Core temperature via tympanic and rectal temperature measurements: update. Boston Marathon Medical Seminar, American Medical Athletic Association, Boston MA, April 1991.
38. Armstrong L.E. Physiological responses during heat acclimation while consuming 4 or 8 grams of NaCl per day. Committee on Military Nutrition Research, National Academy of Sciences, Washington DC, April 1991.
39. Armstrong, L.E. Recent findings regarding human salt requirements during the initial days of living and working in hot environments. USAMRDC Environmental Science Course, USARIEM, Natick MA, May 1991.
40. Armstrong L.E. Hot weather running: Heat illness. Race Seminar, Shenipset Striders, Rockville, CT, February 1992.
41. Armstrong, L.E. Muscle physiology. ACSM Exercise Test Technician Course. The University of Connecticut, Storrs, CT, My 1992.
42. Armstrong, L.E. Prevention of heat illness among fire fighters. Sponsored by Commission on Fire Prevention and Control. Annual Fire School of Connecticut Fire Fighters, Meriden, CT, June 1992.
43. Armstrong, L.E. Preventing Overexposure in the Heat of Summer. Sports Medicine Clinic & YWCA, Manchester, CT, July 1992.
44. Armstrong, L.E. Heat illness among competitive athletes. Falmouth Road Race Medical Clinic. Falmouth Hospital, MA, August 1992.
45. Armstrong L.E., Maresh C.M. Seminar: Body fluid compartments, fluid-electrolyte shifts, measurement techniques. Procter & Gamble Co. Food & Beverage Technology Division, Cincinnati, OH, September 1992.
46. Armstrong L.E., Maresh C.M. Seminar: Role of hydration in health and exercise; fluid-electrolyte movements during stress; fluid replacement. Procter & Gamble Co., Health Care Division, Cincinnati, OH, March 1993.
47. Armstrong L.E. Heat illnesses among tennis players. First annual scientific conference on Sports Medicine and Exercise in Tennis. Sponsored by U.S. Tennis Assoc., Tampa, FL, April 1993.
48. Armstrong L.E. Symptomatic hyponatremia: endurance athletes. Falmouth Road Race Medical Clinic. Falmouth Hospital, MA, August 1993.

49. Armstrong L.E. Beat the Heat. Community Seminar Series sponsored by Sports Medicine & Orthopedics, Manchester, CT, August 1993.
50. Armstrong L.E. Fluid and mineral requirements during exercise. 1993 North American Conference, International Diabetic Athletes Association, Charlton, MA, August 1993.
51. Armstrong, L.E. Muscle physiology. Exercise Metabolism. (2 lectures) ACSM Health Fitness Instructor Course. The University of Connecticut, Storrs, CT, July 1994, July 1995, July 1996.
52. Armstrong, L.E. Is endotoxemia an etiologic factor in heatstroke among distance runners at road races? Falmouth Road Race Medical Clinic. Falmouth Hospital, MA, August 1994.
53. Armstrong, L.E. Training for races in hot environments. Marine Corps Marathon, Pre-race Conference, Washington, D.C., October 1994.
54. Armstrong, L.E., Maresh, C.M. Vitamin and mineral supplements as nutritional aids to exercise performance. International Life Science Institute, Conference on Nutrition and Physical Activity to Optimize Performance and Well-Being, Atlanta, GA, April 1995.
55. Armstrong L.E. Cooling hyperthermic runners and heatstroke patients. Clinical lecture, National Conference of American College Sports Medicine, Cincinnati OH, June 1996.
56. Armstrong, L.E. Heat illnesses: prevention and treatment. Life College, Atlanta GA, July 1996.
57. Armstrong L.E. Cooling hyperthermic runners and heatstroke patients. Annual meeting of New England ACSM, tutorial lecture, Boxborough MA, November 1996.
58. Armstrong L.E. The sweating response to exercise in humans: effects of training status and environmental factors. Tutorial lecture, Annual meeting of New England Chapter of ACSM, Providence RI, Sept. 1997.
59. Armstrong L.E. and Maresh C.M. Can humans avoid and recover from exertional heatstroke? Keynote Lecture, Fifth World Congress of the International Society for Adaptive Medicine, Framingham MA, Sept. 1997
60. Armstrong L.E., Roberts W.O., Epstein Y. Eradication of exertional heatstroke in athletic and military populations. Symposium, Annual Meeting of ACSM National, Orlando FL, June 1998.
61. Armstrong L.E., Montain S.J., Coggan A.R. Does carbohydrate consumption always enhance exercise performance? Conversational Forum, Annual Meeting of ACSM National, Orlando FL, June 1998.
62. Armstrong L.E. Effects of training, environment and host factors on the sweating response to exercise. University of Massachusetts, Amherst MA, October 1998.
63. Armstrong L.E. The physiological and health benefits of a regular exercise program. New Haven Public Libraries, two sites, New Haven CT, August 1999.
64. Armstrong L.E. My career path in exercise science research. Presentation at the Student Breakfast, Annual Conference of the New England Regional Chapter of ACSM, Providence RI, October 1999.
65. Armstrong, L.E. Unique Adaptations and Responses to Earth's Varied Environmental Stressors. National ACSM Conference, Environmental Physiology Special Interest Group Dinner Meeting, Indianapolis IN, June 2000.
66. Armstrong, L.E. Performing in extreme environments. Keynote Lecture, Midwest ACSM Regional Chapter Annual Conference, Grand Rapids, MI, October 2000. Armstrong L.E.
67. Armstrong, L.E. Unique responses and adaptations to earth's varied environmental stressors. Lecture presented at the annual meeting of American College of Sports Medicine, Baltimore MD, June 2001.
68. Armstrong, L.E. Caffeine, body fluid balance, and dehydration. Invited lecture for International Life Science Institute, Washington D.C., May 2002.
69. Armstrong, L.E. Fluid replacement and rehydration strategies. Invited keynote lecture at the annual national conference of the National Athletic Trainers Association. Dallas, TX, June, 2002.
70. Armstrong, L.E. Exercise-associated collapse among athletes. Invited speaker for Connecticut Athletic Trainers Association annual conference, Hartford, CT. June, 2002.
71. Armstrong, L.E. High, Dry or Drowning? A practitioner's guide to heatstroke, dehydration and hyponatremia. Invited speaker at NSCA Sport-Specific Conference, New Orleans, LA. January, 2003.
72. Armstrong, L.E. Measuring Hydration Status. Invited speaker at International Life Science Institute, North America meeting, Washington D.C., May 2003.
73. Armstrong, L.E. Two lectures: (a) Exertional Heatstroke: Cardiovascular Manifestations. (b) Caffeine and Fluid-Electrolyte Balance in Exercising Adults. Invited speaker, Gatorade Sport Science Institute, Barrington IL, Sept. 2003.
74. Armstrong, L.E. Fluid Replacement: Comparison and Critique of Published Position Statements. Invited speaker at ACSM Consensus Roundtable re. Hydration and Physical Activity, Boston, MA, Dec. 2003.

75. Armstrong L.E. The Effects of Caffeine on Fluid-Electrolyte Balance and Athletic Performance. Media Event: Coffee and Your Health: Surprising Findings. New York, NY, Oct. 2004.
 76. Armstrong L.E. Caffeine Effects on Fluid Balance and Behavioral Responses. International Life Sciences Institute, Washington, D.C. Oct. 2004.
 77. Armstrong L.E. Hyponatremia in marathon runners. American Medical Athletic Association Symposium in association with the Marine Corps Marathon, Virginia Medical Center, Alexandria, VA. Oct., 2005.
 78. Armstrong L.E. Does Caffeine/Coffee Dehydrate the Body? Media Event: Coffee and Your Health: Recent Research. New York, NY, Nov. 2005.
 79. Armstrong L.E. Keynote Address: High and Dry: Tales from the edge of a Normal Distribution. Annual Conference of New England Chapter of ACSM. Providence, RI. November 11, 2005.
 80. Armstrong, L.E. Caffeine: Athletic Performance and Whole-Body Hydration State. Media event sponsored by Oldways of Boston, MA. New York City, March 2006.
 81. Armstrong, L.E. Ergogenic Aids: Research at the Human Performance Laboratory, University of Connecticut. Shaklee, Inc. Pleasanton, CA. March 2006.
 82. Armstrong L.E. Pathophysiology of exertional heatstroke. American Medical Athletic Association Symposium in association with the Marine Corps Marathon, Virginia Medical Center, Alexandria, VA. Oct. 2006.
 83. Armstrong L.E. Optimal use of hydration indices. Regional conference of National Strength & Conditioning Association ("Periodization & Planning"), Storrs CT, June 2007.
 84. Armstrong, L.E. Energy, fluid and electrolyte needs of endurance cyclists. Medical-Scientific Conference, in conjunction with 100-mile bike event, Hotter 'n Hell Hundred, Wichita Falls, TX, August, 2007.
 85. Armstrong, L.E. High, Dry and Wet: Tales from the Ends of a Normal Distribution. Founder's Keynote Lecture. Southwest Chapter of American College of Sports Medicine, San Diego, CA, November, 2007.
 86. Armstrong L.E. Exertional heat exhaustion. American Medical Athletic Association Symposium in association with the Marine Corps Marathon, Virginia Medical Center, Alexandria, VA. Oct. 2007.
 87. Armstrong L.E. The Spectrum of Unusual Thermal and Hydration Extremes. Keynote Lecture. Annual Conference of Southeast Chapter of ACSM. Birmingham, AL. February 16, 2008.
- Also see section above titled, "USTA, USOC, IOC, & FIFA: Lectures & Publications"

Invited Lectures in Other Countries

1. Armstrong, L.E. Heat Injury Prevention and Recommendations for Hot Weather Training. Physicians and medics, Gorgas Hospital and Coco Solo Health Clinic, Panama, September, 1985.
2. Armstrong, L.E. Living and exercising in hot-arid environments. Seminar Series: four lectures, U.S. Naval Hospital and GTMO Training Group, Guantanamo Bay, Cuba, April 1989.
3. Armstrong L.E. Thermoregulation of athletes with spinal cord injury. Vista '93 Conference, Jasper National Park, Edmonton, Alberta, Canada, May 1993.
4. Armstrong, L.E. Effects of training status and environmental factors on the sweating response to exercise. International Conference on Dehydration, Rehydration and Exercise in the Heat, Nottingham, England, November 1995.
5. Armstrong L.E. 1. Sweating response to exercise in humans: effects of training status and environmental factors. 2. Responses to moderate and low sodium diets during exercise-heat acclimation. 3. Physiological adaptations during heat acclimatization: strategies and deacclimation. 4. Do carbohydrates in sport drinks always enhance exercise performance? Four invited lectures, International Symposium on Nutrition and Hydration in Sport, Rosario Argentina, September 1997.
6. Armstrong, L.E. Dietary sodium needs during heat acclimation. University of Aberdeen Medical School, Dept. of Environmental & Occupational Medicine, Aberdeen, Scotland, July 1999.
7. Armstrong, L.E. 1. Environmental and Clothing Influences on Performance. 2. Fluid replacement before, during and after physical activity. Two invited lectures presented at IV Simposio Internacional de Atividades Fisicas, Rio De Janeiro, Brazil, July 2000.
8. Armstrong, L.E. Ethical issues in human research. Seminar presented to the RISE Program, University of Puerto Rico at Cayey, PR, October 2001.
9. Armstrong, L.E. Caffeine: effects on exercise performance and fluid-electrolyte balance. Seminar, Loughborough University, Loughborough, England, U.K., June 2003.
10. Armstrong, L.E. Assessing Hydration Status. Seminar, Lausanne Switzerland, Nestle' Research Center. Nov. 2004
11. Armstrong, L.E. Nutritional Strategies for Soccer: Counteracting Heat, Cold, High Altitude and Jet Lag. FIFA Consensus Conference on Sports Nutrition, Zurich Switzerland, Sept. 2005

12. Armstrong L.E. The elusive gold standard for assessing human hydration state. Conference organized by Danone Research. Paris, France. Feb, 2007.
13. Armstrong, L.E. Assessing Hydration Status: Advising Sedentary & Active Adults. Nutrition Science Master's Student Seminar. Loughborough University, Leicestershire, U.K. Invited by Professor Ronald Maughan. March, 2007.
14. Armstrong, L.E. Hydration Assessment Techniques: Use, Misuse and The Elusive Gold Standard. Faculty, Graduate Student, and Undergraduate Student Seminar. University of Wales, Bangor, North Wales. Invited by Professor Neil Walsh. March, 2007.

Interdepartmental and Guest Lectures: UCONN

1. Armstrong, L.E. Water, electrolytes, dehydration, and carbohydrate-electrolyte replacement beverages. Univ. of CT, School of Allied Health Professions, Storrs CT, July 1991.
2. Armstrong, L.E. Research at the University of Connecticut Human Performance Laboratory. Univ. of Connecticut Honors Student Seminar. November 1994, November 1996, November 1999, April 2001.
3. Armstrong, L.E. Fluid-electrolyte balance of athletes: When are sport drinks necessary? Undergraduate Sport Nutrition Course, School of Nutritional Sciences, University of Connecticut. April 1995 - 2001.
4. Armstrong, L.E. Fluid needs of female athletes. Univ. of Connecticut Female Athlete Performance Committee Roundtable Discussion. January 1997.
5. Armstrong, L.E. Fluids and electrolytes in exercise and sport. Univ. of Connecticut Sports Medicine-Athletic Training Group. December, 2001.
6. Armstrong, L.E. Does sleep deprivation affect mental and physical performance? Univ. of Connecticut Athletic Counseling Office, Freshman athlete seminar. October, 2001.
7. Armstrong, L.E. Armstrong, L.E. Sodium and extracellular volume in exercise and sport. Univ. of Connecticut Sports Medicine Physicians and Athletic Trainers. December, 2003.
8. Armstrong, L.E. The recent IOC Consensus Document regarding fluid-electrolyte replacement". University of Connecticut, Sports Nutrition course (NUSC 250), March 2004.
9. Armstrong, L.E. Theories and research from the Human Performance Laboratory. University of Connecticut, College of Pharmacy, Pharmacology & Toxicology Seminar Series, March 2004.
10. Armstrong, L.E. The University of Connecticut Institutional Review Board. University of Connecticut, Neag School of Education Faculty Meeting, November, 2004 and Spring, 2005.
11. Armstrong, L.E. Caffeine and its effects on performance and hydration state. Sports Nutrition Course (NUSC 250), Dept. of Nutritional Sciences, Nancy Rodriguez, Professor. Spring, 2006.



University of
Connecticut

Final Project Report

Revised text appears at pages 19-24 only
30 June 2008

Thermoregulatory and Physiological Strain due to Athletic Equipment

Sponsor:

Mrs. Welch Springer

via

Attorney Paul M. DeMarco

and the legal firm of

Walter, Schneider, Bayless & Chesley Co., LPA

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Table 18. Mean (\pm SD) perceptual ratings measured at five time points ($n = 8$ to 10).
The perceptual instruments are described in the text above.

Uniform Type	Time Point ^a	Perceived Exertion ^b	Thermal	Thirst	Pain Intensity
Control	Pre-RBL	6 \pm 1	4.5 \pm 0.5	2 \pm 1	0 \pm 1
	End RBL	14 \pm 3	6.0 \pm 1.0	5 \pm 2	2 \pm 2
	Start Treadmill	8 \pm 2	5.5 \pm 1.0	3 \pm 1	1 \pm 1
	Min 20	12 \pm 3	6.0 \pm 1.0	5 \pm 2	2 \pm 2
	Final	14 \pm 3	6.0 \pm 2.0	7 \pm 2	3 \pm 3
Partial (no H or SP)	Pre-RBL	6 \pm 1	5.0 \pm 0.5	2 \pm 1	0 \pm 1
	End RBL	16 \pm 2	6.0 \pm 1.0	5 \pm 2	3 \pm 2
	Start Treadmill	8 \pm 2	5.0 \pm 1.0	4 \pm 1	1 \pm 1
	Min 20	15 \pm 3	6.5 \pm 1.0	6 \pm 2	3 \pm 3
	Final	18 \pm 2	7.0 \pm 1.0	8 \pm 1	4 \pm 3
Full Uniform	Pre-RBL	6 \pm 1	4.5 \pm 1.0	2 \pm 1	0 \pm 1
	End RBL	16 \pm 2	6.0 \pm 0.5	5 \pm 1	2 \pm 1
	Start Treadmill	9 \pm 3	5.5 \pm 0.5	4 \pm 2	1 \pm 1
	Min 20	14 \pm 3	7.0 \pm 0.5	6 \pm 1	2 \pm 2
	Final	18 \pm 1	7.5 \pm 0.5	7 \pm 1	4 \pm 3

^a, Pre-RBL, immediately before repetitive box lifting (RBL) task began; End RBL, immediately after the repetitive box lifting (RBL) task ended; Start treadmill, immediately after a 10-min rest period and treadmill walking began; Min 20, measured during the 20th minute of treadmill walking; Final, measured immediately before treadmill walking ended.

Prediction of Rectal Temperature and Heart Rate at the Hypothetical 2-hour Time Point

The statistical regression analysis of the plot lines for Full Uniform, Partial, and Control allowed a prediction of the rectal temperature (Figure 1) and heart rate (Figure 2) values that would have been reached by test subjects, had they continued to exercise longer. The following values were calculated, via regression analysis, as though treadmill walking had continued to the 2-hour time point. The final six data points (25 min period) for each uniform type (Figures 1 and 2) were used.

- Rectal temperature after 2 hours of treadmill walking is predicted to be:
 - Full Uniform – 42.0°C (107.6°F)
 - Partial (no H or SP) – 40.8°C (105.4°F)
 - Control – 39.1°C (102.2°F)
- Heart rate after 2 hours of treadmill walking is predicted to be:
 - Full Uniform – 218 beats/min
 - Partial (no H or SP) – 190 beats/min
 - Control – 163 beats/min

Conclusions

The three experimental trials are named via the following terms:

Control – the no uniform condition in which subjects wore only shorts, socks and sneakers (n = 10 subjects)

Partial (no H or SP) – the Full Uniform minus helmet and shoulder pads (n = 10 subjects)

Full Uniform – shorts, white athletic socks, long socks, sneakers, gloves, jersey, pants, pads on legs, hips, arms (n = 10 subjects)

All subjects completed the Control, Partial, and Full Uniform experiments.

1. Air temperature, air relative humidity, and subject hydration state (i.e., body weight, urine specific gravity) were controlled from day-to-day.
2. Test subjects stopped because of exhaustion, not due to their reaching pre-established rectal temperature or heart rate safety limits.
3. Skin temperature was greater in Full Uniform versus Control (at the neck and forearm) and Full Uniform versus Partial (at the neck). *two*
4. Humidity (%rh) was the same inside the three uniforms (Control, Partial, Full).
5. Sweat rates were similar in Partial and Full Uniform; both of these were greater than Control clothing.
6. The number of test subjects who reached a rectal temperature of 39.0°C (102.2°F) was recorded as follows: Control – 4, Partial – 6, Full Uniform – 6. This level of hyperthermia is considered to be the lower body temperature threshold at which exertional heatstroke begins.
7. The exercise time of Full Uniform was significantly less than Control (P<.05). The exercise time of Partial was significantly less than Control (P<.005) and significantly greater than Full Uniform (P<.005).
8. From Min 20 to Min 40 of treadmill exercise, Partial (no helmet and no shoulder pads) caused an increase of rectal temperature (i.e., due to heat storage in the deep tissues of the body) that was 2.0 times greater than Control; Full Uniform caused an increase of rectal temperature that was 2.7 times greater than Control; the helmet and shoulder pads caused 43% of this increase in rectal temperature.
9. During the entire treadmill exercise bout, Partial Uniform (no helmet or shoulder pads) caused rectal temperature to rise 1.4 times faster than Control, whereas the Full Uniform caused rectal temperature to rise 1.9 times faster than Control. During the entire treadmill exercise bout, the helmet and shoulder pads accounted for 56% of the total rectal temperature rise of the Full Uniform.
10. Blood pressure dropped similarly in all uniform types during the entire protocol (RBL + rest + treadmill exercise), except for systolic pressure post-RBL where the Partial Uniform and the Full Uniform were greater than the Control clothing. This represented hypotension.
11. Heart rate increased similarly in all uniform types during the entire protocol (RBL + rest + treadmill exercise), except near the end of treadmill exercise when the Partial Uniform and the Full Uniform were greater than the Control clothing.
12. Blood constituents were similar in all uniform types.
13. Perceived exertion, thirst, thermal and pain ratings were similar in all uniform types.

15. 14. Change of rectal temperature was significantly correlated with body fat per cent and especially lean body mass.
14. The statistical regression analysis of the lines for the Control, Partial and Full uniforms (see Figure 1 and Figure 2) allow a statistical projection of the physiological values that would have been reached, during a 2-hour exercise bout.
- Rectal temperature after 2 hours of treadmill walking is predicted to be:
 - Full Uniform – 42.0°C (107.6°F)
 - Partial (no H or SP) – 40.8°C (105.4°F)
 - Control – 39.1°C (102.2°F)
 - Heart rate after 2 hours of treadmill walking is predicted to be:
 - Full Uniform – 218 beats/min
 - Partial (no H or SP) – 190 beats/min
 - Control – 163 beats/min

Appendices

The following pages contain forms and scales used during this investigation.

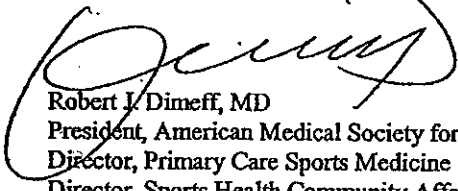
Appendix A – Perceptual Scales: rating of perceived exertion, thermal sensation, thirst, pain

Dr. Dimeff Report Page 4

equipment can and has been used safely during football practice and participation in hot and humid conditions.

It is my opinion that Korey Stringer suffered from water intoxication leading to hyponatremia causing mental status alterations. This subsequently caused confusion in his appearance as he developed EHS, which delayed proper care.

It is my opinion that the placement of warning labels on shoulder pads, helmets, and other football equipment that the use or wearing of such equipment could increase the risk of heat stroke and death would likely have no effect on the behavior of athletes, coaches, equipment managers, athletic trainers, or physicians.



Robert J. Dimeff, MD
President, American Medical Society for Sports Medicine
Director, Primary Care Sports Medicine
Director, Sports Health Community Affairs
The Cleveland Clinic Foundation

Randolph Eichner Deposition Excerpts

Edward Randolph Eichner, M.D.

Page 1

IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF OHIO
EASTERN DIVISION

KELCI STRINGER, Individually,)
and as Representative of the)
Estate of Korey Stringer,)

Plaintiff,)

-vs-

) No. C2 03 665

) JUDGE HOLSCHUH

NATIONAL FOOTBALL LEAGUE, et)

al.,)

) Magistrate Judge Abel

Defendants.)

DEPOSITION OF EDWARD RANDOLPH EICHNER, M.D.

TAKEN ON BEHALF OF THE PLAINTIFF

IN OKLAHOMA CITY, OKLAHOMA

ON AUGUST 28, 2008

REPORTED BY: KAREN DAUPHIN ALBERT, CSR, RPR

Job No.: 189187

Edward Randolph Eichner, M.D.

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1 A. Yes. That's another word for it by some --
2 some authors call it that.

3 Q. What is delusional hyponatremia?

4 A. That means that the sodium is low because
5 it has been diluted by hypotonic fluid or water, but
6 that -- and the most common cause of that is
7 overdrinking water, like when you're running slow in
8 a marathon.

9 But to an extent, the hyponatremia in
10 football two-a-days is also partly delusional. They
11 have a very salty sweat, so they're losing saline, if
12 you will, in their sweat, and then they're drinking,
13 preferentially, water or other fluids that are fairly
14 hypotonic, so they lose some sodium in their sweat,
15 and then what sodium is left in their blood, they
16 dilute it down a little bit by drinking water when
17 they should be drinking saline, if you will, or at
18 least saltier drinks.

19 Q. Was Korey Stringer suffering from water
20 intoxication --

21 A. I don't --

22 Q. -- on July 31, 2001?

23 A. No. No. He was --

24 MR. KELLY: Let her finish, remember.

25 THE WITNESS: Okay.

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1 No. He was dehydrated.

2 Q. (By Ms. Roselle) Can you say to a
3 reasonable degree of medical certainty that Korey
4 Stringer was not suffering from water intoxication on
5 July 31, 2001?

6 MR. KELLY: I'll object.

7 If you know.

8 THE WITNESS: In my opinion, he was
9 not suffering from that form of hyponatremia. He
10 was suffering from the hypovolemic hyponatremia.

11 Q. (By Ms. Roselle) All I'm asking is if your
12 opinion is to a reasonable degree of medical
13 certainty.

14 A. Yes.

15 Q. Is it possible to be suffering from
16 delusional hyponatremia and dehydration at the same
17 time?

18 A. Yes.

19 Q. Okay. Is it possible to be suffering from
20 dehydration and water intoxication at the same time?

21 A. No.

22 Q. Do you consider a sodium level of 125
23 consistent with delusional hyponatremia?

24 A. It's consistent with either type, either
25 delusional or hypovolemic.

**Randolph Eichner
Deposition Exhibit 2C
“Eichner Article”**

HEAT STROKE IN SPORTS: CAUSES, PREVENTION, AND TREATMENT

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KEY POINTS

- Heat stroke is always a risk in summer sports, especially football and running.
- Heat stroke is typically caused by a combination of hot environment, strenuous exercise, clothing that limits evaporation of sweat, inadequate adaptation to the heat, too much body fat, and/or lack of fitness.
- Early recognition and fast treatment of evolving heat stroke can save lives.
- Preventing heat stroke hinges on acclimation, hydration, pacing, cooling, and vigilance.
- Heat stroke is a medical emergency. The life-saving adage is: cool first and transport second.

INTRODUCTION

Summer football brings grueling workouts in brutal heat. For football players in the dog days, mild heat illness is common and grave heat stroke always a threat (Knochel, 1975). Since 1995, on average three players a year have died of heat stroke. Heat stroke also threatens runners and other athletes; in the 2001 Chicago Marathon, a young man in his first marathon collapsed of heat stroke at 26 miles and died soon after.

Heat illness can advance quickly in football players and runners, and early warning signs of heat stroke can be subtle. Yet early diagnosis and proper therapy can save lives; exertional heat stroke should be preventable. This article covers causes of heat stroke in sports and presents tips to recognition, prevention, and treatment.

RESEARCH REVIEW

Causes of Heat Stroke

Overmotivation.

Overmotivated athletes can overheat by doing too much too fast or trying to endure too long. An Australian runner, out of shape, sped to the front of a hot race and kept going hard until he dropped from heat stroke at 4.5 miles (Lee et al., 1990). The same happened to a novice runner who, on a mild day, sped up at the end of a six-mile race (Hanson et al., 1979). Both runners

were lucky to live; speed and metabolic rate influence rectal temperature in distance racing (Noakes et al., 1991).

Agonizing tableaux of endurance were seen at the 1984 Los Angeles Olympic Games and the 1995 Hawaii Ironman Triathlon. In Los Angeles, marathoner Gabriela Andersen-Scheiss, not trained for heat, entered the stadium dazed and wobbling. In a final lap that seemed to last forever, she waved off help and collapsed at the finish. In Hawaii, seven-time winner Paula Newby-Fraser, losing her lead, skipped aid stations late in the run and collapsed near the end. After rest, cooling, and hydration, she was able to walk to the finish (Eichner, 1998).

Similar lessons come from the military. A soldier died of heat stroke marching at night, carrying extra weight. He completed just 2.5 miles (Assia et al., 1985). Running generates about twice the heat of marching. Of 82 heat-stroke cases in Israeli soldiers, 40% were from brief exercise, as in the first three miles of a run. Overmotivation was a risk factor (Epstein et al., 1999).

Football breeds a warrior mentality. Victims of heat stroke are described as "the hardest worker" or "determined to prove himself." During a hard practice on a hot day, the never-quit mentality can work against a player.

The 1-2 Punch.

Most heat-stroke deaths in football occur on Day 1 or 2 of two-a-days. A similar 1-2 punch applies in the military. In studying 1,454 cases of heat illness in Marine-recruit training, researchers implicated heat stress on the prior day as a factor (Kark et al., 1996). So a prime time for heat stroke is the day after an exhausting and dehydrating day in the heat.

Heat and Humidity.

In summer sports, it's not the heat, but the heat and humidity. In football, body temperature rises — in a sawtooth line — ever higher the longer practice goes on. So during a hard practice in full gear, heat stroke is possible at any combination of ambient temperature above 80 °F (26.7 °C) and relative humidity above 40% (Kulka & Kenney, 2002).

Unacclimated.

Getting heat-fit takes time. Lack of acclimation is a cardinal predictor of heat stroke in football. Triathletes unacclimated to the tropical heat of Hawaii also suffer. Acclimation, much of which occurs in a week or two, leads to better drinking and the body holds onto water and salt, increasing blood volume so the heart pumps more blood at a lower heart rate. Heat-fit athletes

also sweat sooner, in greater volume, and over a wider body area, so they stay cooler.

Dehydration.

Athletes in the heat can sweat 1-2 L an hour, and most athletes drink less than they sweat. The result is dehydration. Dehydrating only 2% body weight — just five pounds in a 250-pound linebacker — can impair physical performance (Walsh et al., 1994). Dehydration increases heart rate and decreases cardiac output. Perceived exertion of the work increases as dehydration drains mental sharpness and willpower along with muscle power and endurance. Dehydrated players also heat up faster (Latzka & Montain, 1999).

Uniform Penalty.

The football uniform insulates players. As more gear is added — from shorts and shirt to pads and helmet to full uniform — players heat up faster, get hotter, and cool slower (Kulka & Kenney, 2002). Runners too should avoid vapor-impermeable clothing that limits sweat evaporation. In 1999, actor Martin Lawrence jogged in heavy clothes and a wool hat in 100 °F (37.8 °C) to lose weight. He collapsed with a temperature of 107 °F (41.7 °C) and spent three days in a coma.

Heat Stroke and Body Mass.

Fat athletes are prone to heat stroke. Extra fat is an extra load, increasing exertional heat production. The NFL has nearly 300 players who weigh 300 pounds or more, six times as many as a decade ago. Nor is extra fat the only bulk problem. When a 270-pound player adds 30 pounds of muscle, he can generate more heat, but he does not add enough extra surface area to shed that extra heat. So huge linemen can be heat bombs.

Fitness Protects.

Physical fitness, especially aerobic fitness, confers some of the same physiologic benefits as heat acclimation (Latzka & Montain, 1999). Fitness also makes workouts less taxing. So football players who come to camp fit are at lower risk of heat stroke.

In contrast, lack of fitness increases risk of heat illness. In a study of 391 cases of heat illness in Marine recruits, time to run 1.5 miles (and body mass index) predicted risk. A recruit unable to run 1.5 miles in 12 minutes (and with a body mass index over 22) had eight times the risk of heat illness in basic training as did one with a lower body mass and faster run time (Gardner et al., 1996).

Supplements.

Stimulants speed heat buildup, so products that speed players up heat them up. Amphetamine and cocaine are the most dangerous, but ephedra is the most prevalent. Many dietary supplements tout ephedra for weight loss or quick energy. But ephedra poses many health risks, including heat stroke. Heat-stroke risk is compounded by drugs that impair sweating, like some antihistamines, antispasmodics, and medications for depression.

Recognizing Heat Stroke Beyond Fluids.

Heat stroke in football sometimes seems to hit with surprising speed. When this happens, a common theme of bewildered staff

is, "But he got lots of fluids." The misconception is that hydration prevents heat stroke. The truth is that hydrating is critical but not sufficient to prevent heat stroke. Stress fluids but think "beyond fluids." All the factors described above can work together to cause heat stroke.

Compared to the other common causes of collapse in football — trauma, heart disease, asthma, sudden blood clots tied to sickle cell trait (sickling crisis) — heat stroke is often slow to evolve, and the vigilant observer can detect early warning signs and avoid the worst outcome. Heat stroke is always a threat during hard drills on hot days, especially in hefty players in full gear.

Early Warning.

Early warning signs of impending heat stroke may include irritability, confusion, apathy, belligerence, emotional instability, or irrational behavior. The coach may be the first to note that a player, heating up, can no longer think clearly. Giddiness, undue fatigue, and vomiting can also be early signs. Paradoxical chills and goose bumps signal shutdown of skin circulation, portending a faster rise in temperature. The player may hyperventilate — just as a dog pants — to shed heat; this can cause tingling fingers as a prelude to collapse. Incoordination and staggering — "running like a puppet on a string" — are late signs, followed by collapse with seizure and/or coma. Upon collapse, as in all three football players who died in 2001, core body temperature can be 108 °F (42.2 °C) or higher.

Preventing Heat Stroke

Cooler is Better.

The cooler athletes stay, the better they play. In team sports, take frequent cooling breaks: Provide shade, ice water, and misting fans for rest breaks. As the temperature rises, reduce practice pace and duration and increase rest breaks. Have players sit in cold tubs after practice. Hold practices earlier and later, with more time between — time for rest, recovery, and cooling.

In hot road races, tips include: stay hydrated; run comfortably, avoid long sprints; "read" your body; and seek help early for illness. Confusion can limit self-diagnosis, so race monitors can help. Runners in trouble can become belligerent, refusing to stop until they collapse. Naïve crowds may urge on suffering athletes, chanting, "Keep going, you can make it." Monitors can recognize early warning: incoherence, irrational or bizarre behavior, or poor competitive posture (Eichner, 1998).

Drink Sensibly.

Hydration helps prevent heat stroke, but there is no advantage to consuming fluid in excess of sweat loss. Likewise it's not necessary to overhydrate the night before or during the hours prior to a long run or practice. Teach athletes to drink for their needs. During training have them weigh in before and after a workout and learn to adjust fluid intake to minimize weight loss. If weight loss does occur, rehydration after activity is critical; drink 20-24 ounces of fluid for every pound of weight loss. Also, eat foods with a high water content (fruits & vegetables). A sports drink beats plain water because it has sugars to fuel muscles and brain, flavoring to encourage drinking, and sodium to hold fluid in the body and help replace sweat losses.

Be Prepared.

High heat can overwhelm even physically fit and hydrated players. A week or two of moderate physical activity in the heat, say jogging 30-45 minutes a day, can jump-start heat acclimation. Athletes should never go from a sedentary, air-conditioned life into a hard-charging summer athletic camp.

Bird-dog the Big Guys.

In football, focus on high-risk players. Spot subtle signs of physical or cognitive decline. Weight loss the first few days is fluid loss, not fat loss. Dizziness and drop in blood pressure on standing signal fluid and sodium depletion. Urine should resemble lemonade, not apple juice. Weigh before and after practice. Morning weight should be back up, near baseline, and body temperature should be normal before the player takes the field. When in doubt, hold them out.

Uniform Concerns.

In football, limit gear in the heat. Suit-up in stages in summer camp: shorts and T-shirt the first day or two; then add helmet; then shoulder pads and jersey; finally the full uniform. Remove helmet and pads for fitness runs. Boxers and wrestlers should not run in plastic suits to lose weight.

Counter the Culture.

Some football players are overmotivated by pride and driven by tough coaches. They believe no limits exist. They ignore warning signs. Never let the warrior call the shots. Some runners also have a never-say-die mentality. The man who died of heat stroke in the Chicago Marathon may have pushed the pace trying to keep up with his brother. Heat stroke is rare in female athletes. And in Marines, although attack rates are the same by gender, heat illness is milder in females (Kark et al., 1996). These gender trends raise questions of biology and behavior.

Train, Don't Strain.

Start slow. Athletes cannot safely start full tilt in stifling heat. Other than massive bleeding, exercising all-out in extreme heat is the greatest strain on the cardiovascular system. Pace and duration should "start low and build slow." Don't drive halfway to heaven on the first day.

Off-field Behavior.

Off-field behavior also counts. Athletes sleeping poorly or ill, especially with vomiting, diarrhea, or fever, are more prone to heat stroke. The same applies to taking diuretics or drinking alcohol. Monitor all medications.

Pre-cooling?

Linemen and other athletes at risk of heat stroke may benefit from pre-cooling before workouts. A half hour in a cold bath will reduce core temperature and increase the buffer against heat stroke. Pre-cooling mimics Mother Nature in that after a week of daily exercise in the heat, basal body temperature is reduced about 0.9 °F (0.5 °C) (Buono et al., 1998). Another benefit may be improved hot-weather running or cycling (Booth et al., 1997; Gonzalez-Alonzo et al., 1999). Using cold towels or splashing cold water on face, head, and neck provides a psychological boost but little physiological benefit.

**Treating Heat Stroke
Medical Emergency.**

In heat stroke, every minute counts. When core temperature is very high, body and brain cells begin to die, so fast cooling is vital. Early features are subtle central nervous system (CNS) changes — altered cognition or behavior — and core temperature over 104-105 °F (40.0-40.6 °C). When an athlete collapses, the best gauge of core temperature is rectal temperature; oral, axillary, or ear-canal temperature will not do. Advanced features are collapse with wet skin, core temperature over 106-107 °F (41.1-41.7 °C) and striking CNS changes — delirium, stupor, seizures, or coma (Roberts, 1998).

Cool First.

Field treatment is fast cooling. No faster way to cool exists than dumping the athlete into an ice-water tub. Submerge the trunk — shoulders to hip joints. Research suggests ice-water immersion cools runners twice as fast as air exposure while wrapped in wet towels (Armstrong et al., 1996). The Marines also use ice-water cooling (Kark et al., 1996). Recent field research with volunteer runners suggests cold water may cool as fast as ice water (Clements et al., 2002).

Monitor Closely.

Check the athlete every few minutes for rectal temperature, CNS status, and vital signs. Useful is an indwelling rectal probe with a thermometer. To prevent overcooling, remove the athlete from the tub when rectal temperature drops to 102 °F (38.9 °C). An athlete can be cooled from 108-110 °F (42.2-43.3 °C) to 102 °F (38.9 °C) in 15-30 minutes (Roberts, 1998).

Transport Second.

Cool first, transport second. Send the heat-stroke athlete to the hospital after cooling. With fast cooling, survival rate approaches 100% (Kark et al., 1996). In fact, fast cooling can allow athletes to walk away in good health. For example, yearly at the Falmouth Road Race, up to 10-15 runners collapse with temperatures from 106-110 °F (41.1-43.3 °C), but over a decade nearly all such runners, after ice-water immersion, walked away. After cooling, runners are observed for 20-60 minutes to ensure they are drinking fluids and have normal vital signs and good cognition (Roberts, 1998).

Recovery.

We need more data on recovery. Anecdotally, most runners cooled on-site return to racing in weeks. Some research suggests heat-stroke patients may have brief or lasting heat intolerance, but whether this is innate or a result of the heat stroke is unclear (Shapiro et al., 1979). Other research suggests 90% of heat-stroke patients have normal heat tolerance within two months (Armstrong et al., 1990). Long-term follow-up of 922 cases of heat illness in Marine recruits is encouraging — subsequent serious heat illness occurs in less than 1% of these Marines per year (Phinney et al., 2001). It seems likely that most athletes treated early for heat stroke and educated on preventing it can return safely to their sport within weeks.

SUMMARY

Many factors — environmental and personal — contribute to heat stroke. Early warning signs of impending heat stroke may include irritability, confusion, apathy, belligerence, emotional instability, irrational behavior, giddiness, undue fatigue, chills,

goose bumps, and vomiting. Practical tips for preventing and treating heat stroke in sports are outlined, with the vital adage being: Cool first; transport second. Research on recovery is sparse, but it seems likely that most athletes treated early for heat stroke can soon safely return to their sport.

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HEAT STROKE IN SPORTS: HOW TO PROTECT YOURSELF AND HELP YOUR TEAMMATES

Heat stroke is always a risk in any sport when it's warm, especially in football and in distance running such as the 10-k race. In football, the uniform insulates the player and increases the risk of heat stroke. Heat stroke is possible any time the air temperature is above 80 degrees F and the relative humidity is above 40%. Here are some tips that will help you protect yourself and help your teammates:

- Improving your physical fitness and adjusting your body to the heat over several days lower your risk of heat stroke. Don't jump from an easy, air-conditioned life into a summer athletic camp like football two-a-days.
- Get fit first, and adjust to the heat for a week or two before formal practices begin by jogging 30-45 minutes a day in the heat in shorts and T-shirt. Be prepared.
- The highest risk for heat stroke occurs in the first few days of training in hot weather. The largest and fattest athletes are the most heat-sensitive.
- On the field, read your body, don't defy Mother Nature, and never ignore early warning signs of illness. Train, don't strain. Don't drive yourself halfway to heaven to make the team.

- Take full advantage of every rest break. In football, seek shade, take your helmet off, and get in front of a misting fan. Sit in a cold tub right after practice. The cooler you stay, the better you play.
- Off the field, never skip meals, get plenty of fluids and salt, avoid alcohol, stay cool when you can, and get plenty of sleep.
- Heat stroke is a medical emergency. Early recognition and proper treatment can save lives.
- You may be the first to notice early signs of heat stroke in a teammate or running buddy. If so, pull him out, cool him down, and get help fast. When in doubt, cool first and transport to the hospital second.
- Other tips on what to do and what to watch for to avoid heat stroke in sports are listed in the tables.

**TABLE S1.
WHAT TO DO TO AVOID HEAT STROKE.**

Come to the first practice physically fit and heat-fit

Report fever or illness to the athletic trainer

Show all your medicines to the trainer

Avoid stimulants like ephedra

Stay hydrated

Favor sports drinks over plain water

Watch urine: Should be plentiful and pale

Watch weight: Early weight loss is fluid loss

After a workout, drink 1½ pints of fluid for every pound of weight lost

Dizziness on standing up is caused by fluid and salt loss

(See additional chart on back)

**TABLE S2.
WHAT TO WATCH FOR:
SIGNS OF HEAT STROKE**

Fuzzy thinking

- Can't follow the plays
- Seems confused
- Suddenly forgetful
- Runs the wrong way

Bizarre behavior

- Talks nonsense
- Blank stare
- Laughs or cries at wrong time
- Yells in rage at coach or peers
- Wants to fight for no good reason

Physical decline

- Begins to lose coordination
- Sudden or unusual fatigue
- Nausea and vomiting
- Chills and goose bumps
- Overbreathing, tingly fingers
- Wobbles or staggers, collapses
- Seizure or coma

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